Human Flight to Lunar and Beyond – Re-Inventing Operations Paradigms

DSN Support for Human Space Flight Program

Joe Statman
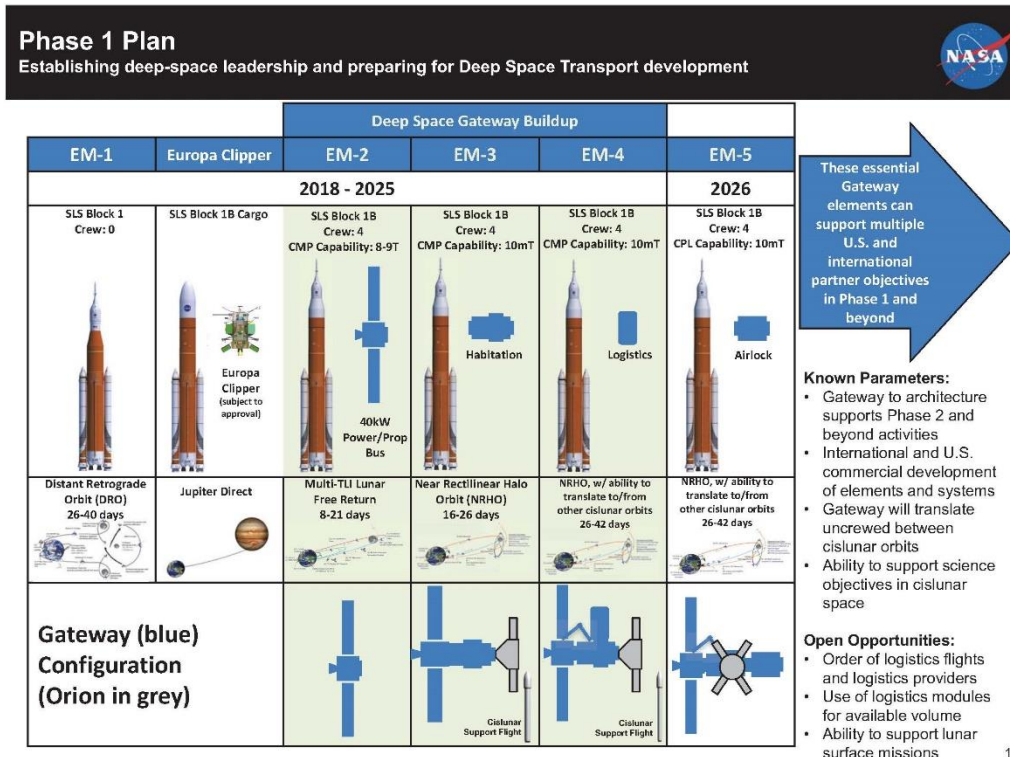Deep Space Network
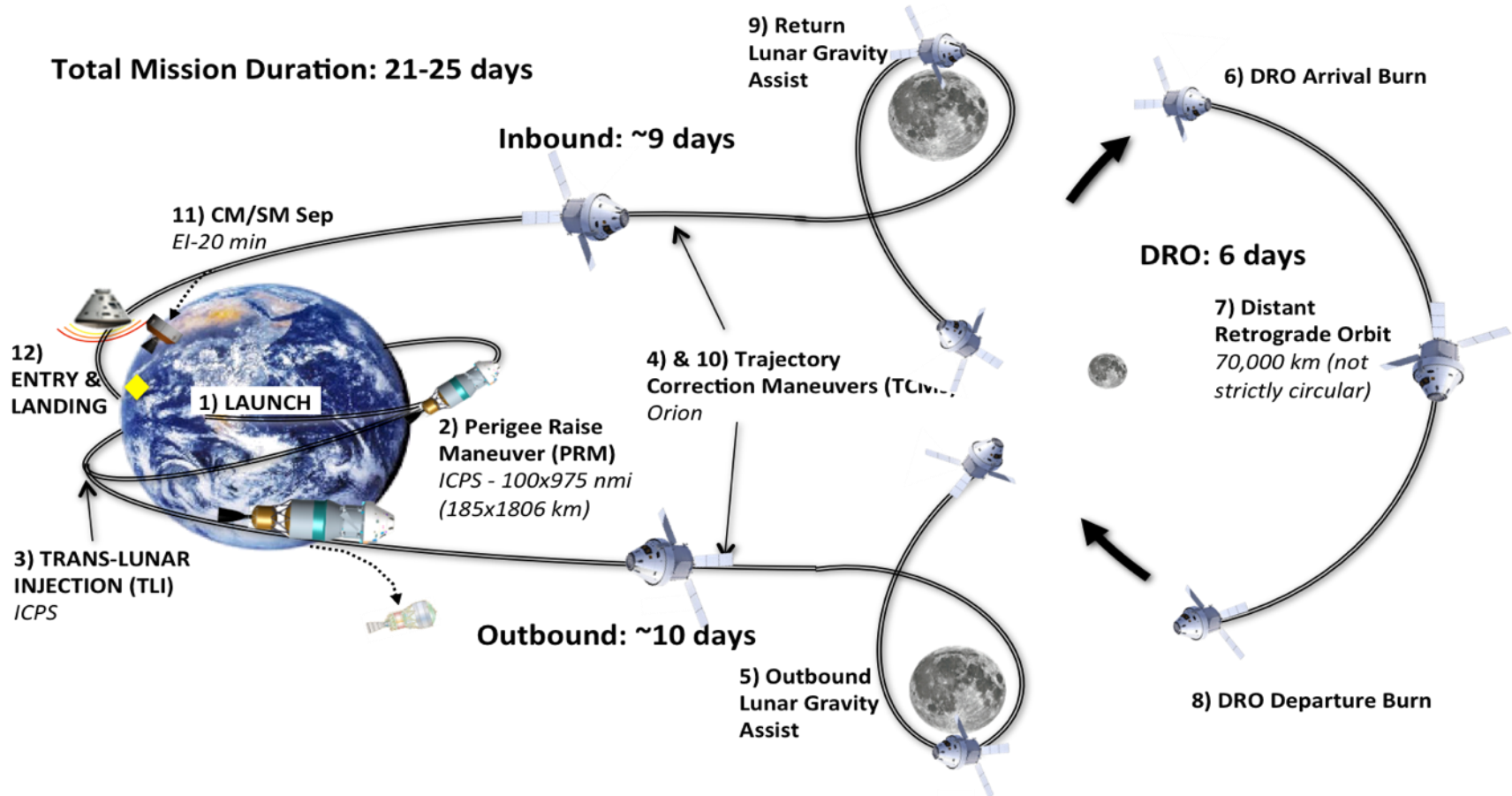Jet Propulsion Laboratory, California Institute of Technology.

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Introduction

- For the first time since the Apollo era, NASA is planning on sending astronauts on flights beyond Low Earth Orbit (LEO)
    - EM-1 will be unmanned and EM-2, carrying astronauts, will follow
- Longer-term plan is being developed for deep space exploration

Exploration Possible Mission

Total Mission Duration: 21-25 days

9) Return Lunar Gravity Assist

6) DRO Arrival Burn

Inbound: ~9 days

11) CM/SM Sep
EI-20 min

DRO: 6 days

7) Distant Retrograde Orbit
70,000 km (not strictly circular)

12) ENTRY & LANDING

1) LAUNCH

2) Perigee Raise Maneuver (PRM)
ICPS - 100x975 nmi (185x1806 km)

4) & 10) Trajectory Correction Maneuvers (TCM)
Orion

3) TRANS-LUNAR INJECTION (TLI)
ICPS

Outbound: ~10 days

5) Outbound Lunar Gravity Assist

8) DRO Departure Burn

- Multiple NASA networks will support each Exploration mission
 - Based on distance from Earth

# Approach to Deep Space Mission Support

- DSN sites were optimized for operations above Geo-Synchronous Orbits (GEO)
  - Provide close to 24x7 coverage, depending on spacecraft trajectory
- DSN equipment is optimized to track missions above GEO altitude
  - Large fully-steerable antennas with precision pointing
  - Cryogenic receivers for weak signals
  - High power transmitters
  - Specialized algorithms
- NASA's Near-Earth Network (NEN) and Space Network (SN) are optimized to track sub-GEO missions

Simplified DSN Visibility - looking down on the Earth´s North Pole

Goldstone View

Earth

Madrid View

Canberra View

GEO

30,000 Km

LEO (600 Km)
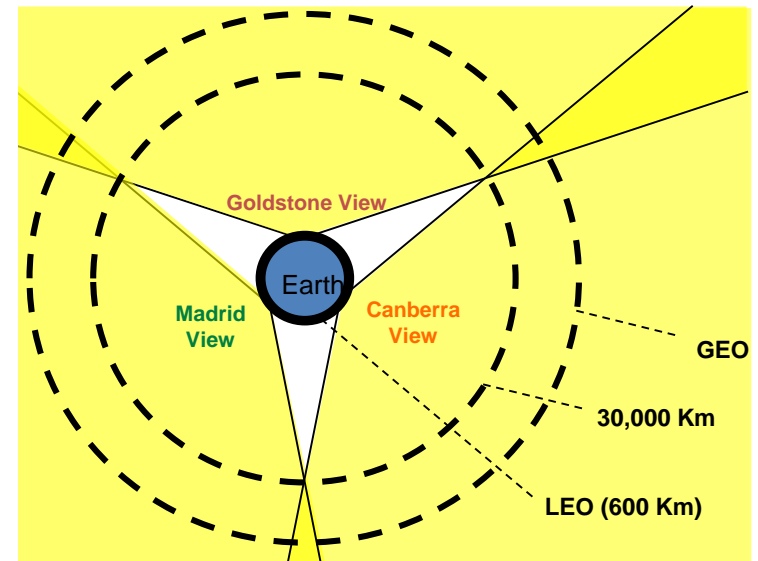
SLS and Orion – DSN Roles
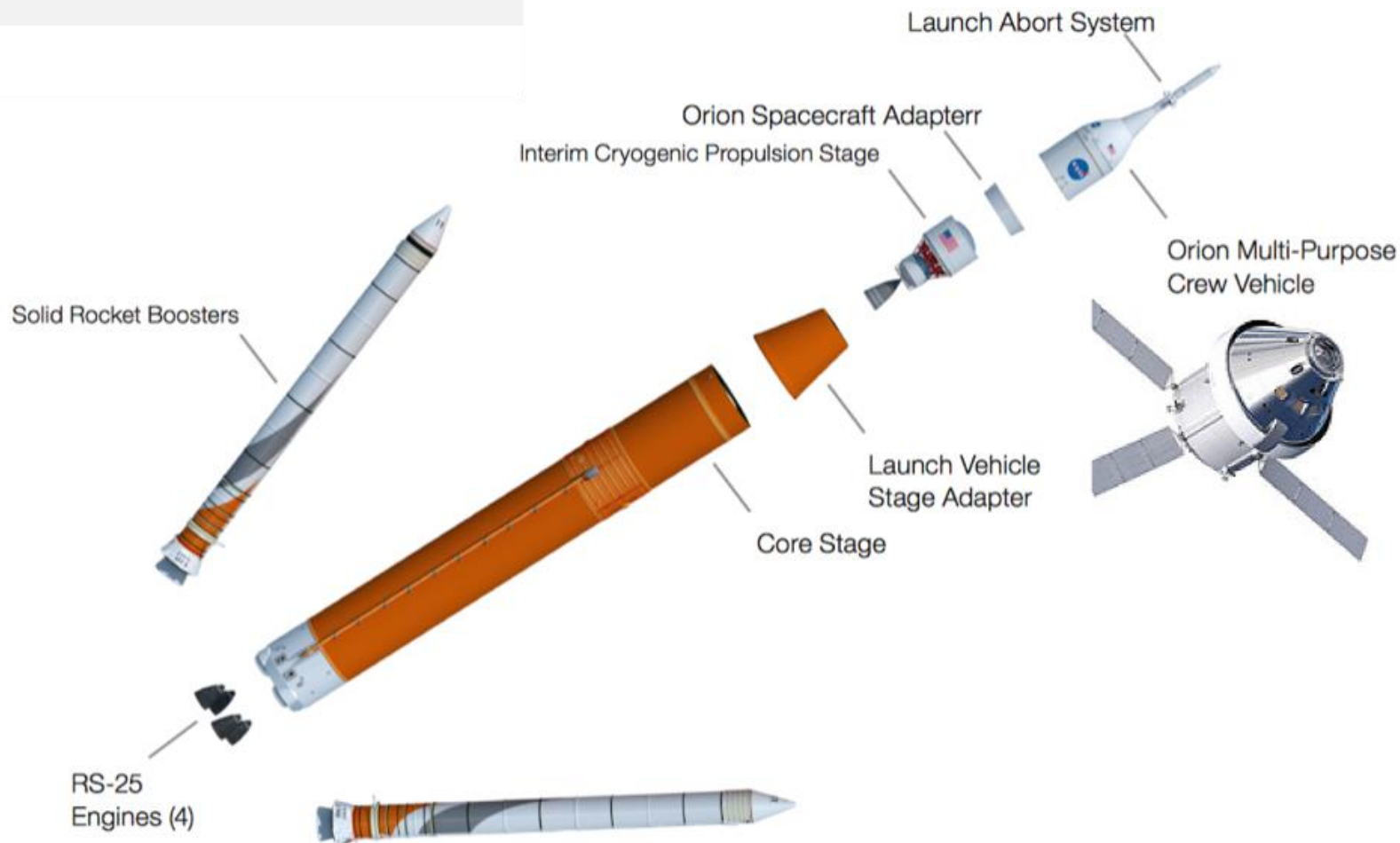
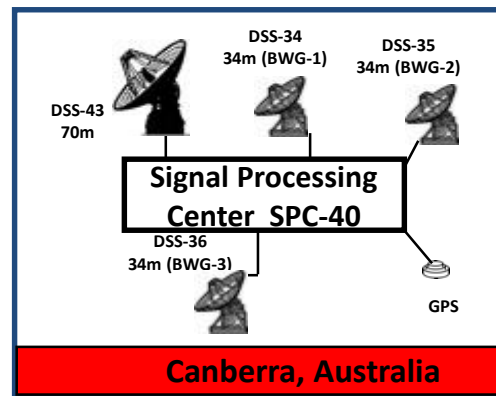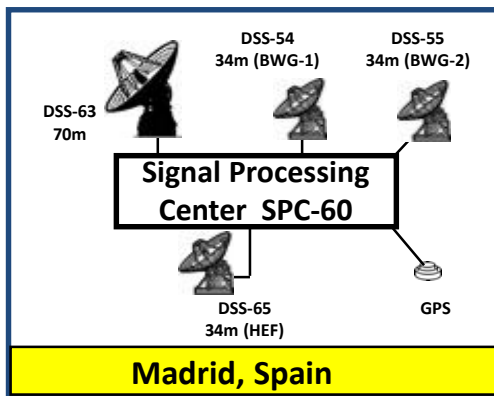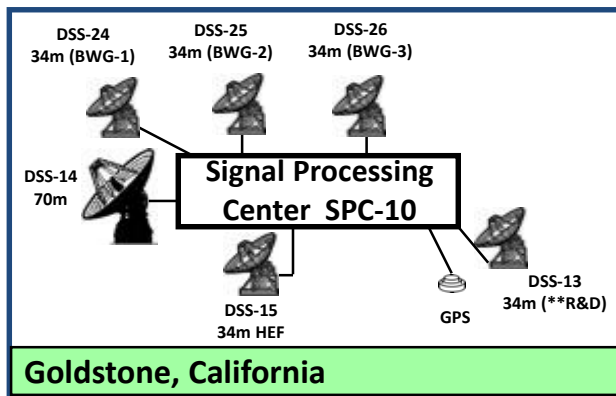| Space Launch System	ICPS (for EM-1), EUS (after EM-1)	Orion
Not tracked by DSN	**EUS is tracked by DSN. iCPS is not**	**Tracked by DSN**

Communications Approach
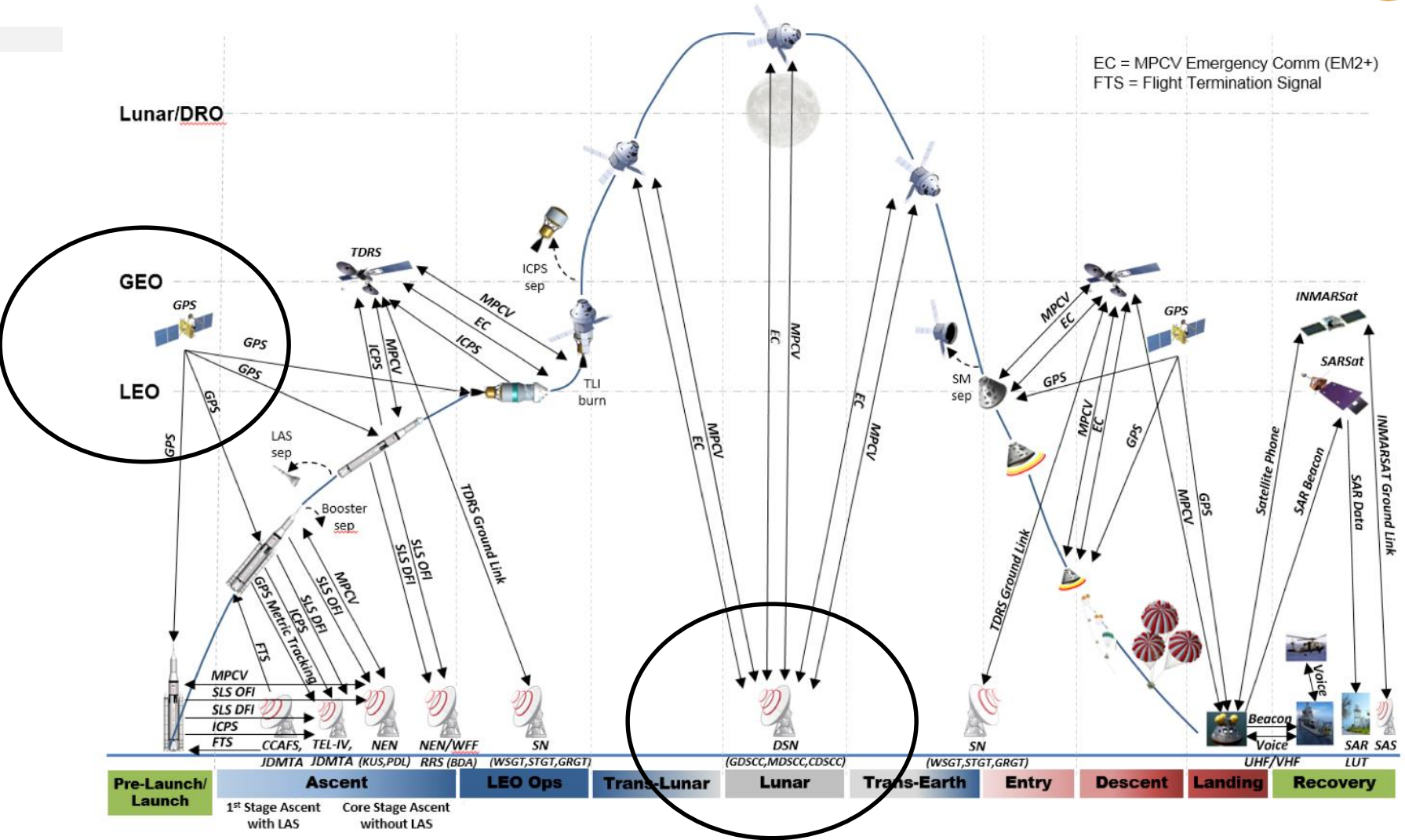
- DSN focus is on tracking at altitudes of GEO and higher
    - Hand-offs to/from SN/NEN for sub-GEO tracking

Communications/Navigation Needs

- DSN is designed as a multi-mission capability (~40 missions supported at any time) with broad adherence to international inter-operability standards
  – The HSF missions are supported within this framework
- HSF will be supported near-24x7 coverage at altitudes of >GEO with a prime 34m antenna, and a backup 34m antenna if needed
  - Additional 34m antennas were added at the Canberra site and are being added elsewhere
- While EM-1 uses just S-band communications, the DSN is equipped to support future S-band, X-band, and Ka-band communications
  - Plans for optical comm capability are underway

Design of Communications Link

- DSN and Orion were upgraded to enable DSN support
  - Getting more consistent with CCSDS formats (that DSN uses)
  - Adding non-regenerative capability and residual carrier
    - Enable Doppler and ranging
  - Moving to newer, more powerful error-correcting codes
    - E.g. Low Density Parity Codes (LDPC)
- For EM-1 and EM-2, the approach (driven by cost-effectiveness) was to selectively upgrade Orion and the DSN

Navigation Approach

- For LEO missions, GPS is available for navigation
  - But beyond GEO, DSN-based ranging and Doppler is needed
- For EM-x missions, above-GEO navigation will use Doppler and ranging from DSN sites
  - Challenging task, especially at Mars distances, but well-developed
  - Under consideration is the addition of a set of 3-way Doppler measurements that involve DSN stations and non-DSN stations

- The Ops scenario for Human missions is different than for robotic
  - Joint effort of DSN and missions to implement adjustments
- Examples: Emergency communications, voice/video, human in the loop operations, uplink of news/movies/sports, and private 2-way medical conferences and family conferences.
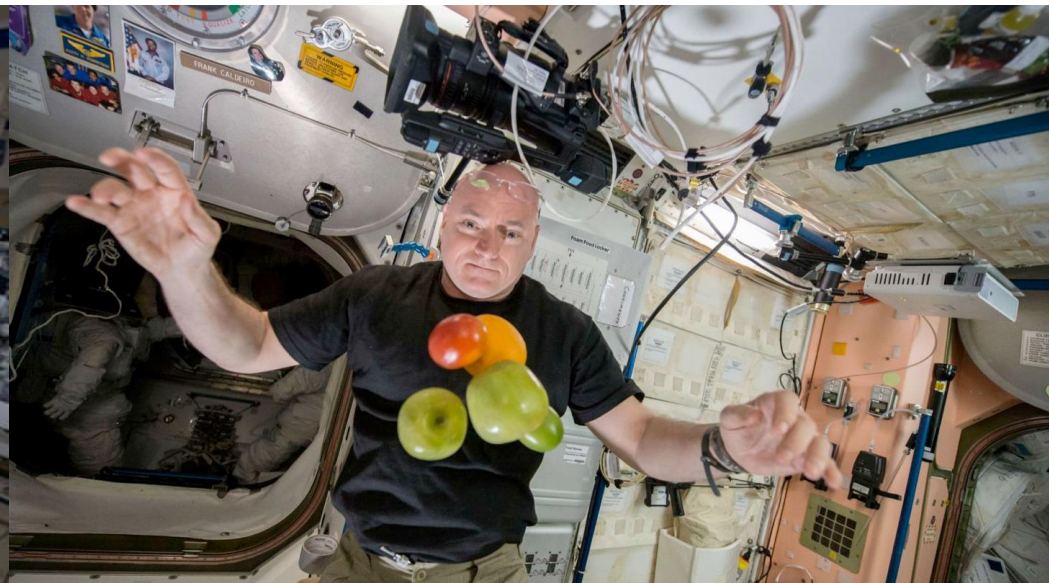
Voice and Video Challenge

- Orion will need voice and, preferably, video connection with Earth
  - Operations have to contend with latency. At a minimum, latency will be the Round-Trip-Light-Time (RTLT)
  - Imagine trying to have a 2-way discussion (audio or video) with an astronaut, with a 2-3 seconds or more delay inserted (for lunar distances) or 20 minutes delay (for Mars distances)!
- Partially addressed by tightening delays in the system
  - Though cannot overcome RTLT

- The DSN is ready to support planning for Human missions to lunar distances
  - Including the Initial Cis-Lunar Habitat (ICH)

- And support Human exploration further into space